

**NIST TIME AND FREQUENCY BULLETIN  
NISTIR 6604-5**

**NO. 522    MAY 2001**

|  |   |
|--|---|
| 1. GENERAL BACKGROUND INFORMATION . . . . .                                      | 2 |
| 2. TIME SCALE INFORMATION . . . . .  | 2 |
| 3. PHASE DEVIATIONS FOR WWVB AND LORAN-C . . . . .                               | 4 |
| 4. BROADCAST OUTAGES OVER FIVE MINUTES AND WWVB<br>PHASE PERTURBATIONS . . . . . | 5 |
| 5. NOTES ON NIST TIME SCALES AND PRIMARY STANDARDS . . . . .                     | 5 |
| 6. BIBLIOGRAPHY . . . . .  | 5 |
| 7. SPECIAL ANNOUNCEMENTS . . . . .   | 7 |

This bulletin is published monthly. Address correspondence to:

Gwen E. Bennett, Editor  
Time and Frequency Division  
National Institute of Standards and Technology  
325 Broadway  
Boulder, CO 80303-3328  
(303) 497-3295  
Email: [bennett@boulder.nist.gov](mailto:bennett@boulder.nist.gov)

**NOTE TO SUBSCRIBERS:** Please include your address label (or a copy)  
with any correspondence regarding this bulletin.



---

U.S. DEPARTMENT OF COMMERCE, DONALD L. EVANS, Secretary  
TECHNOLOGY ADMINISTRATION, Dr. Cheryl L. Shavers, Under Secretary of Commerce for Technology  
NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY, Karen H. Brown, Acting Director

## 1. GENERAL BACKGROUND INFORMATION

### ABBREVIATIONS AND ACRONYMS USED IN THIS BULLETIN

|       |   |         |               |
|-------|---|---------|---------------|
| BIPM  | - Bureau International des Poids et Mesures           |         |               |
| CCIR  | - International Radio Consultative Committee          |         |               |
| Cs    | - Cesium standard                                     |         |               |
| GOES  | - Geostationary Operational Environmental Satellite   |         |               |
| GPS   | - Global Positioning System                           |         |               |
| IERS  | - International Earth Rotation Service                |         |               |
| LORAN | - Long Range Navigation                               |         |               |
| MC    | - Master Clock  |         |               |
| MJD   | - Modified Julian Date                                |         |               |
| NVLAP | - National Voluntary Laboratory Accreditation Program |         |               |
| NIST  | - National Institute of Standards and Technology      |         |               |
| NOAA  | - National Oceanic and Atmospheric Administration     | ns      | - nanosecond  |
| SI    | - International System of Units                       | $\mu$ s | - microsecond |
| TA    | - Atomic Time   | ms      | - millisecond |
| TAI   | - International Atomic Time                           | s       | - second      |
| USNO  | - United States Naval Observatory                     | min     | - minute      |
| UTC   | - Coordinated Universal Time                          |         |               |
| VLF   | - very low frequency                                  |         |               |

## 2. TIME SCALE INFORMATION

The values listed below are based on data from the IERS, the USNO, and NIST. The UTC(USNO,MC) - UTC(NIST) values are averaged measurements from up to 10 GPS satellites (see bibliography on page 5). UTC-UTC(NIST) data are on page 3.

| 0000 HOURS COORDINATED UNIVERSAL TIME |       |                                |  |
|---------------------------------------|-------|--------------------------------|--|
| APR 2001                              | MJD   | UT1-UTC(NIST)<br>( $\pm 5$ ms) | UTC(USNO,MC)-UTC(NIST)<br>( $\pm 20$ ns) |
| 5                                     | 52004 | + 22 ms                        | 0 ns                                     |
| 12                                    | 52011 | + 14 ms                        | -3 ns                                    |
| 19                                    | 52018 | + 10 ms                        | -6 ns                                    |
| 26                                    | 52025 | + 4 ms                         | -11 ns                                   |

The master clock pulses used by the WWV, WWVH, WWVB, and GOES time code transmissions are referenced to the UTC(NIST) time scale. Occasionally, 1 s is added to the UTC time scale. This second is called a leap second. Its purpose is to keep the UTC time scale within  $\pm 0.9$  s of the UT1 astronomical time scale, which changes slightly due to variations in the rotation of the Earth.

**NOTE:** No positive leap second will be inserted at the end of June 2001.

Positive leap seconds, beginning at 23 h 59 min 60 s UTC and ending at 0 h 0 min 0 s UTC, were inserted in the UTC timescale on 30 June 1972, 1981-1983, 1985, 1992, 1993, 1994, and 1997, and on 31 December 1972-1979, 1987, 1989, 1990, 1995, and 1998. There have been 22 leap seconds in total.

The use of leap seconds ensures that UT1 - UTC will always be held within  $\pm 0.9$  s. The current value of UT1 - UTC is called the DUT1 correction. DUT1 corrections are broadcast by WWV, WWVH, WWVB, and GOES and are printed below. These corrections may be added to received UTC time signals in order to obtain UT1.

|                    |  |
|--------------------|--|
| DUT1 = UT1 - UTC + | +0.2s beginning 0000 UTC 13 April 2000   |
|                    | +0.1s beginning 0000 UTC 19 October 2000 |
|                    | +0.0s beginning 0000 UTC 01 March 2001   |

The deviation of UTC(NIST) from UTC has been within  $\pm 100$  ns since July 6, 1994. The table below shows values of UTC - UTC(NIST) as supplied by the BIPM in their Circular T publication for the most recent 350 day period in which data are available. Data are given at ten day intervals. Five day interval data are available in Circular T.

**0000 Hours Coordinated Universal Time**

| DATE          | MJD   | UTC-UTC(NIST) ns |
|---------------|-------|------------------|
| Apr 25, 2000  | 51659 | 17               |
| May 5, 2000   | 51669 | 17               |
| May 15, 2000  | 51679 | 17               |
| May 25, 2000  | 51689 | 18               |
| June 4, 2000  | 51699 | 18               |
| June 14, 2000 | 51709 | 20               |
| June 24, 2000 | 51719 | 23               |
| July 4, 2000  | 51729 | 24               |
| July 14, 2000 | 51739 | 24               |
| July 24, 2000 | 51749 | 24               |
| Aug 3, 2000   | 51759 | 26               |
| Aug 13, 2000  | 51769 | 25               |
| Aug 23, 2000  | 51779 | 22               |
| Sep 2, 2000   | 51789 | 12               |
| Sep 12, 2000  | 51799 | 6                |
| Sep 22, 2000  | 51809 | 0                |
| Oct. 2, 2000  | 51819 | -8               |
| Oct. 12, 2000 | 51829 | -13              |
| Oct. 22, 2000 | 51839 | -19              |
| Nov. 1, 2000  | 51849 | -25              |
| Nov. 11, 2000 | 51859 | -22              |
| Nov. 21, 2000 | 51869 | -21              |
| Dec. 1, 2000  | 51879 | -16              |
| Dec. 11, 2000 | 51889 | -9               |
| Dec. 21, 2000 | 51899 | -5               |
| Dec. 31, 2000 | 51909 | -3               |
| Jan. 10, 2001 | 51919 | 2                |
| Jan. 20, 2001 | 51929 | 7                |
| Jan. 30, 2001 | 51939 | 11               |
| Feb. 9, 2001  | 51949 | 11               |
| Feb. 19, 2001 | 51959 | 5                |
| Mar. 1, 2001  | 51969 | 1                |
| Mar. 11, 2001 | 51979 | 0                |
| Mar. 21, 2001 | 51989 | -2               |
| Mar. 31, 2001 | 51999 | 3                |

### 3. PHASE DEVIATIONS FOR WWVB AND LORAN-C

- WWVB - The values shown for WWVB are the time differences between the time markers of the UTC(NIST) time scale and the first positive-going zero voltage crossover measured at the transmitting antenna. The uncertainty of the individual measurements is  $\pm 0.5 \mu\text{s}$ . The values listed are for 1300 UTC.
- LORAN-C - The values shown for Loran-C represent the daily accumulated phase shift (in ns). The phase shift is measured by comparing the output of a Loran receiver to the UTC(NIST) time scale for a period of 24 h. If data were not recorded on a particular day, the symbol (-) is printed.

The master stations monitored are Dana, IN (8970) and Fallon, NV (9940). The monitoring is done from the NIST laboratories in Boulder, Colorado.

**Note: The values shown for Loran-C are in nanoseconds.**

| DATE     | MJD   | UTC(NIST)-WWVB (60 kHz)         | UTC(NIST) - LORAN PHASE (ns) |                         |
|----------|-------|---------------------------------|------------------------------|-------------------------|
|          |       | ANTENNA PHASE ( $\mu\text{s}$ ) | LORAN-C (DANA) (8970)        | LORAN-C (FALLON) (9940) |
| 04/01/01 | 52000 | 5.47                            | + 503                        | - 153                   |
| 04/02/01 | 52001 | 5.47                            | - 330                        | + 5                     |
| 04/03/01 | 52002 | 5.47                            | - 481                        | + 73                    |
| 04/04/01 | 52003 | 5.47                            | + 89                         | + 128                   |
| 04/05/01 | 52004 | 5.47                            | - 302                        | - 60                    |
| 04/06/01 | 52005 | 5.48                            | - 294                        | + 24                    |
| 04/07/01 | 52006 | 5.47                            | + 205                        | - 303                   |
| 04/08/01 | 52007 | 5.47                            | - 126                        | - 394                   |
| 04/09/01 | 52008 | 5.45                            | + 101                        | + 227                   |
| 04/10/01 | 52009 | 5.45                            | + 156                        | + 184                   |
| 04/11/01 | 52010 | 5.45                            | - 556                        | - 30                    |
| 04/12/01 | 52011 | 5.50                            | - 152                        | + 123                   |
| 04/13/01 | 52012 | 5.50                            | - 26                         | + 437                   |
| 04/14/01 | 52013 | 5.50                            | + 38                         | - 454                   |
| 04/15/01 | 52014 | 5.50                            | - 363                        | - 89                    |
| 04/16/01 | 52015 | 5.50                            | - 144                        | - 296                   |
| 04/17/01 | 52016 | 5.47                            | - 260                        | + 109                   |
| 04/18/01 | 52017 | 5.47                            | + 328                        | - 422                   |
| 04/19/01 | 52018 | 5.47                            | - 233                        | - 176                   |
| 04/20/01 | 52019 | 5.46                            | + 370                        | - 75                    |
| 04/21/01 | 52020 | 5.55                            | + 205                        | + 473                   |
| 04/22/01 | 52021 | 5.55                            | - 69                         | + 219                   |
| 04/23/01 | 52022 | 5.56                            | - 252                        | - 232                   |
| 04/24/01 | 52023 | 5.56                            | + 250                        | + 28                    |
| 04/25/01 | 52024 | 5.56                            | + 52                         | - 401                   |
| 04/26/01 | 52025 | 5.56                            | + 221                        | - 371                   |
| 04/27/01 | 52026 | 5.55                            | + 167                        | + 461                   |
| 04/28/01 | 52027 | 5.55                            | - 217                        | - 532                   |
| 04/29/01 | 52028 | 5.55                            | + 481                        | - 341                   |
| 04/30/01 | 52029 | 5.55                            | + 294                        | - 200                   |

#### 4. BROADCAST OUTAGES AND WWVB PHASE PERTURBATIONS

| OUTAGES OF 5 MINUTES OR MORE |          |       |           |           |       | PHASE PERTURBATIONS |          |     |           |         |
|------------------------------|----------|-------|-----------|-----------|-------|---------------------|----------|-----|-----------|---------|
| WWVB 60 kHz                  |          |       |           |           |       |                     |          |     |           |         |
| Station                      | APR 2001 | MJD   | Began UTC | Ended UTC | Freq. |                     | APR 2001 | MJD | Began UTC | End UTC |
| WWVB                         | 4/2      | 52001 | 1320      | 1333      |       |                     |          |     |           |         |
|                              | 4/7      | 52006 | 0202      | 1253      |       |                     |          |     |           |         |
|                              | 4/11     | 52010 | 1035      | 1105      |       |                     |          |     |           |         |
|                              |          |       | 1155      | 1210      |       |                     |          |     |           |         |
|                              | 4/12     | 52011 | 1105      | 1210      |       |                     |          |     |           |         |
|                              |          |       | 0515      | 0545      |       |                     |          |     |           |         |
|                              | 4/14     | 52013 | 0230      | 0250      |       |                     |          |     |           |         |
|                              | 4/23     | 52022 | 1917      | 1936      |       |                     |          |     |           |         |
|                              |          |       | 2037      | 2058      |       |                     |          |     |           |         |
|                              | 4/27     | 52025 | 0805      | 0830      |       |                     |          |     |           |         |
| 4/30                         | 52029    | 0052  | 0125      |           |       |                     |          |     |           |         |
|                              |          |       | 1523      | 1641      |       |                     |          |     |           |         |
|                              |          |       | 1848      | 1908      |       |                     |          |     |           |         |
| WWW                          |          |       |           |           |       |                     |          |     |           |         |
| WWVH                         |          |       |           |           |       |                     |          |     |           |         |

#### 5. NOTES ON NIST TIME SCALE AND PRIMARY STANDARDS

Primary frequency standards developed and maintained by NIST are used to provide accuracy (rate) input to the BIPM. NIST-7, which has served as the U.S. primary standard since 1994 is being replaced by NIST-F1, a cesium fountain frequency standard. The uncertainty of the new standard is currently 1.7 parts in  $10^{15}$ .

The AT1 scale is run in real time using data from an ensemble of cesium standards and hydrogen masers. It is a free-running scale whose frequency is maintained as constant as possible by choosing the optimum weight for each clock that contributes to the computation.

UTC(NIST) is generated as an offset from our real-time scale AT1. It is steered in frequency towards UTC using data published by the BIPM in its Circular T. Changes in the steering frequency will be made, if necessary, at 0000 UTC on the first day of the month, and very occasionally at mid-month. A change in frequency is limited to no more than  $\pm 2\text{ns/day}$ . The frequency of UTC(NIST) is kept as stable as possible at other times.

UTC is generated at the BIPM using a post-processed time-scale algorithm and is not available in real-time. The parameters that we use to generate UTC(NIST) in real-time are therefore based on an extrapolation of UTC from the most recent data available.

#### 6. BIBLIOGRAPHY

Allan, D.W.; Hellwig, H.; and Glaze, D.J., "An accuracy algorithm for an atomic time scale," Metrologia, Vol.11, No.3, pp.133-138 (September 1975).

Allan, D.W. and Weiss, M.A., "Accurate time and frequency transfer during common view of a GPS satellite," Proc. 34th Annual Symposium on Frequency Control, p.334 (1980).

Allan, D.W. and Barnes, J.A., "Optimal time and frequency using GPS signals," Proc. 36th Annual Symposium on Frequency Control, p.378 (1982).

Drullinger, R.E.; Glaze, D.J.; Lowe, J.P.; and Shirley, J.H., "The NIST optically pumped cesium frequency standard," IEEE Trans. Instrum. Meas., IM-40, 162-164 (1991).

Glaze, D.J.; Hellwig, H.; Allan, D.W.; and Jarvis, S., "NBS-4 and NBS-6: The NIST primary frequency standards," Metrologia, Vol.13, pp.17-28 (1977).

Wineland, D.J.; Allan, D.W.; Glaze, D.J.; Hellwig, H.; and Jarvis, S., "Results on limitations in primary cesium standard operation," IEEE Trans. Instrum. Meas., IM-25, pp.453-458 (December 1976).



Table 7.1 is a list of the parameters that are used to define UTC(NIST) with respect to our real-time scale AT1. To find the value of UTC(NIST) - AT1 at any time T (expressed as a Modified Julian Day, including a fraction if needed), the appropriate equation to use is the one for which the desired T is greater than or equal to the entry in the  $T_0$  column and less than the entry in the last column. The values of  $x_{ls}$ ,  $x$ , and  $y$  for that month are then used in the equation below to find the desired value. The parameters  $x$  and  $y$  represent the offset in time and in frequency, respectively, between UTC(NIST) and AT1; the parameter  $x_{ls}$  is the number of leap seconds applied to both UTC(NIST) and UTC as specified by the IERS. Leap seconds are not applied to AT1.

| Table 7.1<br>$UTC(NIST) - AT1 = x_{ls} + x + y \cdot (T - T_0)$ |                 |             |                 |                |                               |
|---|-----------------|-------------|-----------------|----------------|-------------------------------|
| Month   | $x_{ls}$<br>(s) | $x$<br>(ns) | $y$<br>(ns/day) | $T_0$<br>(MJD) | Valid until 0000 on:<br>(MJD) |
| Sep 99  | -32             | -195426     | -40.5           | 51422          | 51452                         |
| Oct 99  | -32             | -196641     | -40.5           | 51452          | 51483                         |
| Nov 99  | -32             | -197896.5   | -40.0           | 51483          | 51513                         |
| Dec 99†   | -32             | -199096.5   | -40.0           | 51513          | 51533                         |
| Dec 99  | -32             | -199896.5   | -41.0           | 51533          | 51544                         |
| Jan 00  | -32             | -200347.5   | -40.5           | 51544          | 51575                         |
| Feb 00  | -32             | -201603     | -40.5           | 51575          | 51604                         |
| Mar 00  | -32             | -202777.5   | -40.5           | 51604          | 51635                         |
| Apr 00  | -32             | -204033     | -40.5           | 51635          | 51665                         |
| May 00  | -32             | -205248     | -40.25          | 51665          | 51696                         |
| Jun 00  | -32             | -206495.75  | -40.25          | 51696          | 51725††                       |
| Jul 00  | -32             | -207663     | -40.0           | 51725††        | 51757                         |
| Aug 00  | -32             | -208943     | -39.5           | 51757          | 51788                         |
| Sep 00  | -32             | -210167.5   | -39.0           | 51788          | 51818                         |
| Oct 00  | -32             | -211337.5   | -39.0           | 51818          | 51849                         |
| Nov 00  | -32             | -212546.5   | -40.0           | 51849          | 51879                         |
| Dec 00  | -32             | -213746.5   | -40.0           | 51879          | 51910                         |
| Jan 01  | -32             | -214986.5   | -40.0           | 51910          | 51941                         |
| Feb 01  | -32             | -216226.5   | -39.0           | 51941          | 51969                         |
| Mar 01  | -32             | -217318.5   | -39.5           | 51969          | 52000                         |
| Apr 01  | -32             | -218543     | -39.0           | 52000          | 52030                         |
| May 01  | -32             | -219713     | -39.5           | 52030          | 52061                         |
| Jun 01  | -32             | -220937.5   | -39.5*          | 52061          | 52091                         |

† Rate change in mid-month

†† Rate change one day early

\*Provisional rate

## 7. SPECIAL ANNOUNCEMENTS

### TRACEABLE FREQUENCY CALIBRATIONS (Now NVLAP Certified)

Laboratories needing traceable frequency calibrations can get them by subscribing to the NIST Frequency Measurement and Analysis Service. This service is offered on a lease basis by NIST to provide an easy and inexpensive means to obtain traceability of a laboratory frequency standard and, in addition, to calibrate other devices in the lab. This service has been designed for ease of operation and as a practical calibration tool.

All necessary hardware and software is provided by NIST. Users must provide their own oscillator(s) and an ordinary telephone line so that NIST can access the system by modem. A total of five oscillators can be calibrated at the same time. Radio signals from GPS satellites are used and the measurement uncertainty is  $\pm 2 \times 10^{-13}$  per day. Any frequency from 1 Hz to 120 MHz can be measured in 1 Hz increments.

The calibration data are displayed in color and a graph is plotted daily for each oscillator. Data are also stored on disk. The user can call up any of the data and view them onscreen or in the form of plots. Up to 5 months of data can be plotted on one graph.

The system plots are easy to read and understand. The system manual is written clearly and the NIST staff is available by telephone to assist. The modem connection allows NIST to access the data and to prepare a monthly traceability report, which is mailed to the user.

Frequency sources of any accuracy can be calibrated. The FMAS is particularly useful at the highest levels of performance. This is because each user of the system contributes information and calibration data for the others. If an uncertainty arises, it is possible for NIST to call by modem to another user nearby. In this way problems in data interpretation can be resolved.

NVLAP certification requirements for frequency measurement are met by following the NIST-FMAS operating manual. This service does not eliminate the NVLAP audits but, when installed and operated per the NIST guidelines, audit requirements are easily met.

NIST retains title to the equipment and supplies. All necessary replacement parts are replaced by overnight shipment. Training for use of the system is available if requested by the user.

The NIST Frequency Measurement and Analysis Service provides a complete solution to nearly all frequency measurement and calibration problems. For a free information package, please contact Michael Lombardi at (303) 497-3212, E-mail at [lombardi@boulder.nist.gov](mailto:lombardi@boulder.nist.gov), or write to: Michael Lombardi, NIST, Division 847, 325 Broadway, Boulder, CO 80303.

---

### IMPORTANT NOTICE!

The Time and Frequency Bulletin data are now online at

[www.boulder.nist.gov/timefreq/](http://www.boulder.nist.gov/timefreq/)

---

AN EQUAL OPPORTUNITY EMPLOYER  
NIST TIME AND FREQUENCY BULLETIN  
NISTIR 6604-5  
NO. 522 MAY 2001

U.S. Department of Commerce  
Technology Administration  
National Institute of Standards and Technology  
Time and Frequency Division  
Boulder, Colorado 80303-3328

---

FIRST-CLASS MAIL  
POSTAGE & FEES PAID  
NIST  
Permit No. G195

OFFICIAL BUSINESS  
Penalty for Private Use, \$300

GWEN BENNETT  
DIVISION 847 COPY 7  
NIST  
325 BROADWAY  
BOULDER, CO 80303